MAGPIE CREEK SECTION 205 ECOSYSTEM RESTORATION
SACRAMENTO, CALIFORNIA

SUPPLEMENTAL REPORT

GEOTECHNICAL OFFICE REPORT

APRIL 2003

U.S. ARMY CORPS OF ENGINEERS
SOUTH PACIFIC DIVISION – SACRAMENTO DISTRICT
GEOTECHNICAL BRANCH – SOIL DESIGN SECTION

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1. Introduction. Magpie Creek is located in northern portion of the City of Sacramento and McClellan Air Force Base (Figure 1). At Raley Blvd., just west of McClellan, Magpie Creek waters are diverted into the Magpie Creek Diversion Channel. The Diversion Channel flows into Robla Creek, which flows into the Natomas East Main Drainage Canal (NEMDC). Downstream of the Diversion Channel, the original Magpie Creek flows into the NEMDC. During floods, both Magpie Creek and the Diversion Channel overtop, resulting in flooding on McClellan and Raley Blvd. A Detailed Project Report (DPR) for the Magpie Creek Section 205 Project was completed in April 1996. The report recommended increasing the channel capacity by excavating the channel, enlarging the existing levee on the left bank, and constructing a new levee on the right bank of the Magpie Creek Diversion Channel. Environmental issues now prevent the excavation of the channel. The current project is investigating raising the left bank levee on the Diversion Channel between Raley Blvd. and Vinci Ave and constructing a maintenance road at the landside toe. This report briefly summarizes information presented in the April 1996 DPR and presents new information obtained and analyses performed since the DPR.

2. Existing Levee Geometry. The existing levee consists of two basic cross sections in the project area. A near-90 degree bend to the right (north) separates the two cross sections. The upstream portion has a 9 foot wide crest and sideslopes varying from about 2.2H:1V to 2.5H:1V on both the land and watersides. On the landside, the levee height is about 6 feet above natural ground. On the waterside, the levee height is about 4 feet, with a waterside berm 2 to 5 feet wide, with a near-vertical slope of approximately 6 to 8 feet down to the channel bottom. The downstream section has a 10-foot wide crest, landside slope between 2.2H:1V and 2.5H:1V, and waterside slope between 1H:1V and 1.5H:1V. On the landside, the levee height is 2 to 4 feet above natural ground. In general, the levee height decreases going downstream toward Vinci Avenue. On the waterside, the levee height is about 8 feet, with a waterside berm 2 to 5 feet in width, with a near-vertical slope of about 4 feet down to the channel bottom. There is no waterside slope protection or landside excavated toe ditch. The crest is covered with a thin layer of sand and gravel. Most of the levee is vegetated with grass and an occasional bush on the steep waterside slope that goes down into the channel. There are some bare patches where the soil is exposed.

3. Existing Explorations. Soil borings, conducted by the Corps of Engineers and others, exist along the alignment of Magpie Creek and the Diversion Channel (Figure 1). In the current study area, between Raley Boulevard and Vinci Street, there are five soil borings performed by Raney Geotechnical in 1989 for a proposed subdivision. Those boring logs are shown on Figure 2. The Raney Geotechnical borings (maximum depth 15 feet below ground surface) are all located on the right bank of the diversion channel within the

downstream 700 lineal feet of the project area. Therefore, there was no existing soil boring information on the left-bank levee itself or the subsurface soils underneath the levee. The existing borings indicate subsurface soils consist primarily of silty sands, silts, and lean clays, with occasional sands at depths greater than 20 feet. These soils are often cemented (locally known as "hardpan") and have high SPT blow counts (mostly greater than 30). One of the Raney Geotechnical borings, 2F-89-RG12, shows a poorly graded sand at shallow depth (8.4 feet below ground surface). Groundwater was not encountered in any of the Raney Geotechnical borings. Groundwater was encountered in one soil boring upstream of the project area at a depth of 8.4 feet below ground surface and in another boring downstream of the project area at a depth of 65 feet below ground surface.

4. New Explorations. Because there were no existing borings on the left side of the channel in the current project area and one existing boring from the opposite side indicated a shallow sand layer (potential underseepage problem), borings were drilled through the left bank levee into the subsurface to accurately determine soil conditions. Four borings (2F-03-20 through –23) were drilled to a depth of 35 feet below the top of levee between 10 and 11 March 2003. Split spoon samples were collected every two feet for the depth of the boreholes. Locations of the borings are shown on Figure 1. Logs of the borings are shown on Figures 3 through 5. One boring (2F-03-20) was drilled where the original Magpie Creek veers off from the diversion channel because old channel beds typically contain sand and gravel layers. One boring (2F-03-21) was drilled where the Natural Resource Conservation Service (NRCS) soil map indicates a different soil horizon on the surface. Two borings (2F-03-22 and –23) were drilled across from boring 2F-89-RG12 to determine if the shallow sand layer extends under the diversion channel. These locations were chosen to obtain representative coverage of the entire project area. Because a shallow sand layer in boring 2F-03-20 showed high exit gradients in underseepage analysis, an additional boring (2F-03-24) was drilled halfway between borings 2F-03-20 and 2F-03-21 on 28 March 2003.

5. Soil Conditions. The new soil borings indicate the levee consists primarily of sandy clay and clayey sand, with minor amounts of silty sand. In all borings except 2F-03-24, the foundation soils consist of a blanket layer of clay, clayey sand, or silty sand, underlain by poorly graded sand. The blanket layer varies from 4 to 6 feet thick. The poorly graded sand varies from 2 to 6 feet thick and is underlain by a hardpan layer of sandy clays and silty sands. A second poorly graded sand layer exists under the hardpan at depths of 16 to 18 feet below the top of the levee. In boring 2F-03-24, the foundation soils consist of silty and clayey sands, sandy clays, and silts. Groundwater was not encountered in any of the new borings.

6. Determination of PFP and PNP for Existing (Without Project) Conditions.

6.1. General. The 1996 DPR lists a Probable Failure Point (PFP) of the existing left-bank levee as elevation 47.0 feet (the top of the existing levee) and a Probable Non-failure Point (PNP) as elevation 46.9 feet (one-tenth of a foot below the top of levee), but provides no documentation of how those values were determined. Slope stability analysis performed for the DPR indicates end-of-construction and rapid drawdown factors of safety of 4.4 and 13.5 respectively for the existing levee. The high factors of safety are due to the high shear strength of the dense and very stiff cemented foundation soils. However, the DPR analysis used a flatter slope than the maximum 1.5H:1V waterside slope in the downstream portion of the current project area. The DPR does not document any seepage analysis having been performed. It was decided to perform underseepage modeling using the new soil borings and to perform a rapid drawdown slope stability model of the steep downstream waterside levee slope.

6.2. Slope Stability. Soil properties used in the analysis are given in Table 1. The properties were based on values used for the 1996 DPR. The computer program UTEXAS4, developed by Dr. Stephen Wright for the Corps of Engineers, was used for slope stability analysis. The rapid drawdown analysis was performed using a waterside levee slope of 1H:1V. The rapid drawdown slope stability model indicates factors of safety of 1.29 with a pre-drawdown water surface at the top of levee and 1.35 with a pre-drawdown water surface three feet below the top of levee. EM 1110-2-1913 lists minimum factors of safety of 1.0 to 1.2 for rapid drawdown for levees.

Table 1. Strength Parameters for Slope Stability Analysis

Material	Unit Weight (lbs/ft^3)	C' (lbs/ft^2)	Phi' (degrees)	C (lbs/ft^2)	Phi (degrees)
Levee	134	200	32	1200	0
Silty Sand	135	100	32	200	29
Hardpan	130	1000	40	1000	20
Sand	124	0	42	0	42

6.3. Underseepage. Permeability values used in the analyses are shown on Table 2. Permeability values were assigned based on values given in Technical Memorandum No. 3-424 for material type and fines content. Underseepage analysis was performed using both the GMS computer program and blanket theory calculations using the procedures in Appendix B of EM 1110-2-1913. Underseepage analysis was conducted using soil profiles from borings 2F-03-20 and -21. Exit gradients were only calculated for the upper sand layer, since the lower sand layer is too deep to be exposed in the diversion channel. For boring 2F-03-21, an exit gradient of 0.23 was calculated with a water surface at the levee crest. For boring 2F-03-20, exit gradients of 0.45 and 0.34 were calculated for water surfaces at the levee crest and 1 foot below the levee crest, respectively. Underseepage analysis was not conducted for borings 2F-03-22 and –23 because the levee crest is only about 2.5 feet above landside ground, which is insufficient differential head to produce unacceptably high exit gradients. ETL 1110-2-555 gives a maximum exit gradient for levees of 0.3 at the landside toe.

Table 2. Permeabilities for Seepage Analysis

Material	K_h (ft/day)	K_v (ft/day)
Levee	0.3	0.05
Clay (80% fines)	0.3	0.075
Clayey Sand (15-30% fines)	2.3	0.57
Clayey Sand (40% fines)	2.0	0.5
Sand (10-15% fines)	4.0	1.0
Sand (5% fines)	5.7	1.4

6.4. PNP/PFP Values. There are no slope stability problems for the existing levee. Exit gradients at the location of boring 2F-03-20 are above Corps criteria for water surfaces 1 foot or less below the crest, but the levee has overtopped during past flood events with no seepage or piping reported. The primary threats to the existing levee are overtopping and erosion of the narrow waterside berm encroaching into the levee section. Given the cemented nature of most of the subsurface soils, the erosion rate is likely to be slow. The levee curve developed for the existing left-bank Magpie Creek Diversion Channel levee is shown in Figure 6. The probability of failure (Pr(f)) was set at zero at the levee toe. The PFP (85% Pr(f)) was set at the top of the levee. The PNP (15% Pr(f)) was set at one foot below the top of levee.

7. Determination of PFP and PNP for With Project Conditions.

7.1. General. The maximum levee raise being considered for this project is just under two feet. For simplicity and conservatism, all analyses presented in this section were performed for a levee raise of two feet with the water surface at the top of the raised levee. The raising consists of the waterside levee slope continued upwards at the existing slope, a crest width of 12 feet, and a 2H:1V landside slope down to existing ground.

7.2. Slope Stability. Rapid drawdown slope stability analysis of the downstream steep waterside slope indicated a factor of safety of 1.27. This is above the factor of safety criteria given in EM 1110-2-1913. Steady-state seepage slope stability was conducted on the taller levee section in the upstream portion of the project area. The factor of safety for large failure arcs encompassing the entire slope is 1.7 and the factor of safety for small failure arcs at the landside toe is 1.2. The factor of safety for small failure arcs is below the 1.4 minimum required by EM 1110-2-1913. However, that analysis did not include the one-foot high, 12-foot wide maintenance road which will be built at the landside levee toe as part of this project. Repeating the analysis including the road indicated a factor of safety of 1.48, which is above the minimum criteria.

7.3 Underseepage. Underseepage analysis conducted with the soil profiles for borings 2F-03-20, -21, and –23 indicate exit gradients of 0.67, 0.28, and 0.34 respectively with a water surface at the top of the raised levee. While the addition of the one-foot tall maintenance road will reduce the last exit gradient to 0.3 or lower, some additional means of underseepage mitigation will be required at boring 2F-03-20. Because there is no pervious sand layer at boring 2F-03-24, blanket theory is not applicable, and seepage at the landside toe was considered by the steady state slope stability analysis for small failure arcs (see paragraph 7.2).

7.4. Underseepage Remediation. Four primary options exist for underseepage remediation. They are:

Cutoff wall (slurry or sheet pile)
Landside relief wells
Landside berm
Landside pervious toe drain

Cutoff walls are not considered a viable option for Magpie Creek because they would not be cost-effective given the short length of remediation required (maximum 560 lineal feet). Relief wells are also not considered a viable option given the shallow depth of the pervious sand layer, the high cost of obtaining additional real estate, and the high potential for vandalism at the project site. The landside berm and landside pervious toe drain options were evaluated. A landside berm would need to be 3 feet high and 20 feet wide at boring 2F-03-20 to obtain exit gradients within the criteria. Given the high cost of obtaining additional real estate, the landside berm is not the preferred alternative. Figure 9-33 of EM 1110-2-1901 was used to determine the minimum required width of a landside pervious toe drain. A width of 3 feet results in an exit gradient of 0.06. Due to the difficulty of constructing such a narrow trench, a minimum width of 10 feet is recommended. The trench should be 5 feet deep, for a penetration of one foot into the pervious sand layer. Boring 2F-03-20 is 160 lineal feet from the western edge of the Raley Boulevard pavement. Boring 2F-03-24 (no underseepage problem) is 560 lineal feet from the western edge of the Raley Boulevard pavement, so that is the maximum length of the pervious toe drain. Due to the relatively low anticipated flow, a collection pipe within the drain is not required. The drain should be filled with coarse gravel or drain rock and wrapped in geotextile to prevent fines from migrating into the drain. The planned landside maintenance road may be built on top of the drain. A schematic of the pervious toe drain is shown on Figure 8.

7.5. PNP/PFP Values. With no slope stability problems and the underseepage problem at boring 2F-03-20 taken care of with a landside pervious toe drain, the primary threats to the existing levee are overtopping and erosion of the narrow waterside berm encroaching into the levee section. Given the cemented nature of most of the subsurface soils, the erosion rate is likely to be slow. The levee curve developed for the with-project left-bank Magpie Creek Diversion Channel levee is shown on Figure 7. The probability of failure (Pr(f)) was set at zero at the levee toe. The PFP (85% Pr(f)) was set at the top of the raised levee. The PNP (15% Pr(f)) was set at one foot below the top of the raised levee.

8. Borrow Material. For levee construction the Corps recommends soils with a maximum particle diameter of 3 inches, a minimum of 15% fines (silt and clay size particles), with the fines portion having a maximum liquid limit of 45 and a plasticity

index between 7 and 15, with no organic material or debris. There are two proposed borrow sources for this project. One is located between Ascot Avenue and the Diversion Channel and west of Dry Creek Road (see Figure 1) and is hereinafter referred to as the SAFCA borrow site. SAFCA has placed material excavated from a previous project in a stockpile which will be used for Magpie Creek. The other proposed borrow source is material excavated from the pervious toe drain trench. It is recommended that soils from the SAFCA borrow site be sampled and tested during PED to determine their suitability for this project.

9. Constructibility. The relatively narrow crest width of both the existing and the raised levee may make compaction difficult using standard driven compactors. Smaller compaction equipment may be required. Typical construction problems with toe drains are improper depth of the drain, groundwater entering the excavation, and sideslope instability. The drain must penetrate the shallow pervious sand layer to be effective. To ensure the drain is constructed to the proper depth, additional shallow soil borings between Raley Boulevard and boring 2F-03-24 are recommended during PED. These borings may also further refine (reduce) the length of the required toe drain. Groundwater entering the toe drain excavation interferes with placement of the geotextile and the pervious trench fill material. In that situation, dewatering is required. Given the deep nature of groundwater over the project area, it is not likely that dewatering will be required for this project. Excavations over 4 feet in depth may be unstable. Due to the potential instability, OSHA regulates excavations greater than 4 feet in depth. These regulations require, among other items, shoring or sloping back of the trench walls if humans are to enter the trench. Due to relatively deep groundwater and relatively shallow depth of water in the Diversion Channel most of the time, soft soils are not likely to be a problem for this project, unless construction occurs during or shortly after a heavy rain. It is recommended that construction take place during the summer months to avoid the possibility of encountering soft soils.

10. Conclusions. With the exception of a short section (maximum 560 lineal feet) immediately downstream of Raley Boulevard, there are no underseepage or slope stability problems associated with the proposed levee raise on the left bank levee of the Magpie Creek Diversion Channel. A pervious toe drain, approximately 5 feet deep and 10 feet wide, will be constructed under the planned maintenance road to alleviate an underseepage problem in the area immediately downstream of Raley Boulevard.

11. Recommendations. The following items are recommended for the next phase of the project:

a. Collect bulk samples and perform grain size, water content, Atterberg limits, and moisture-density tests of the stockpiled soil in the SAFCA borrow site to determine it's suitability for this project. If there is a possibility that the soil may be contaminated, chemical testing may also be required.

b. Drill 3 shallow (about 12 feet below existing ground) soil borings between Raley Boulevard and boring 2F-03-24 to further define (and possibly reduce) the dimensions of the pervious toe drain required in this area.

12. References

U.S. Army Corps of Engineers, Sacramento District, Magpie Creek, California, Section 205, Detailed Project Report, March 1996.

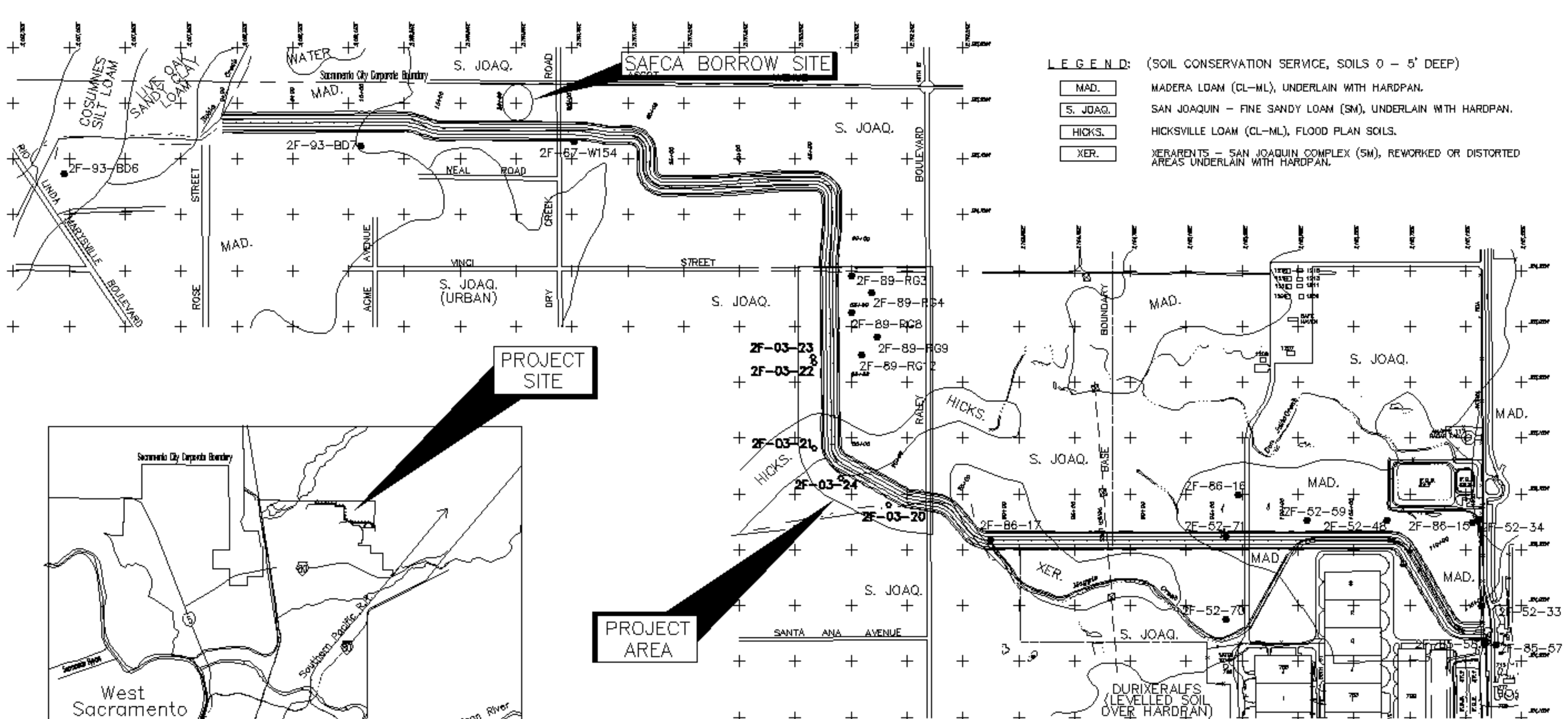
U.S. Army Corps of Engineers, Headquarters, EM 1110-2-1913, Design and Construction of Levees, 20 April 2000.

U.S. Army Corps of Engineers, Headquarters, EM 1110-2-1901, Seepage Analysis and Control for Dams, 30 September 1986.

U.S. Army Corps of Engineers, Headquarters, ETL 1110-2-555, Design Guidance on Levees, 30 November 1997.

U.S. Army Corps of Engineers, Headquarters, ETL 1110-2-566, Risk-Based Analysis in Geotechnical Engineering for Support of Planning Studies, 28 May 1999.

U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Memorandum No. 3-424, Investigation of Underseepage and its Control: Lower Mississippi River Levees, October 1956.

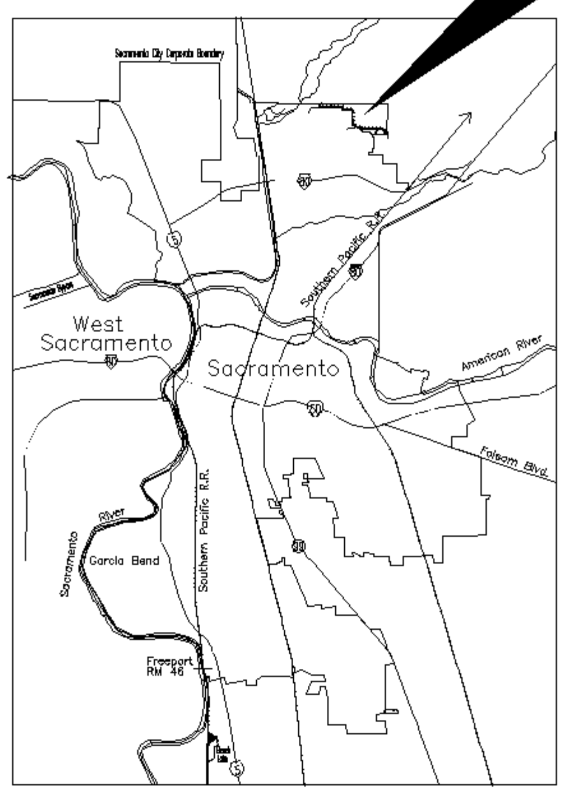


LOCATION OF EXPLORATIONS AND SOILS DISTRIBUTION

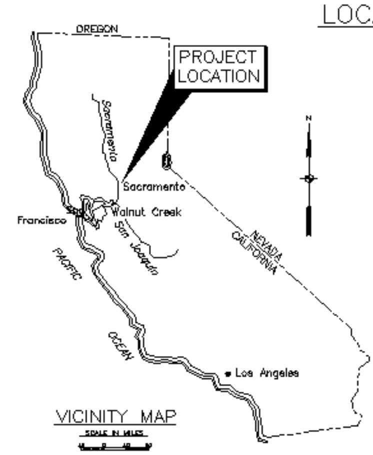
SCALE: 1" = 800'

L E G E N D: (SOIL CONSERVATION SERVICE, SOILS 0 – 5' DEEP)

MAD.	MADERA LOAM (CL–ML), UNDERLAIN WITH HARDPAN.
S. JOAQ.	SAN JOAQUIN – FINE SANDY LOAM (SM), UNDERLAIN WITH HARDPAN.
HICKS.	HICKSVILLE LOAM (CL–ML), FLOOD PLAN SOILS.
XER.	XERARENTS – SAN JOAQUIN COMPLEX (SM), REWORKED OR DISTORTED AREAS UNDERLAIN WITH HARDPAN.



LOCATION MAP
NOT TO SCALE



VICINITY MAP

N O T E S:

1. LEGEND AND NOTES ARE SHOWN ON FIGURE NOS. 2 AND 3.
2. LOGS OF EXPLORATIONS ARE SHOWN ON FIGURE NOS. 2 THROUGH 5.
3. THE DISTRIBUTION OF AGRICULTURAL SOIL TYPES IS BASED ON SHEET 2 OF THE SCS SOIL SURVEY OF SACRAMENTO COUNTY, APRIL 1993.

GRAPHIC SCALE

1"= 800' 0 400' 800' 1600' 2400'

Designed by: J. B.
Dwn by: R.L.T.
Reviewed by:

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SACRAMENTO, CALIFORNIA

SACRAMENTO DISTRICT
IN-HOUSE DESIGN
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SACRAMENTO, CA 95814-2922

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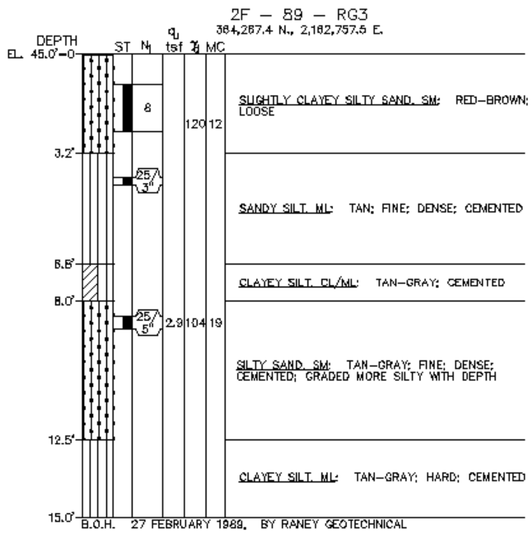
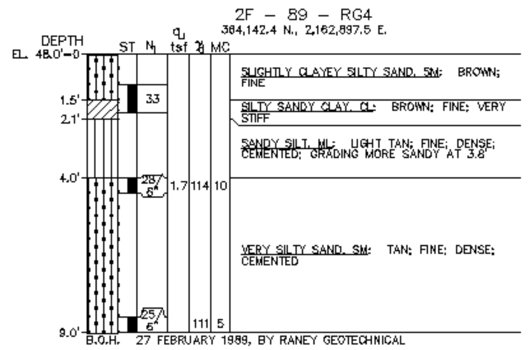
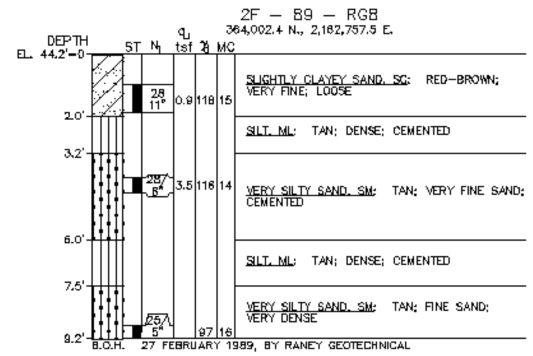
MAGPIE CREEK SUPPLEMENTAL REPORT

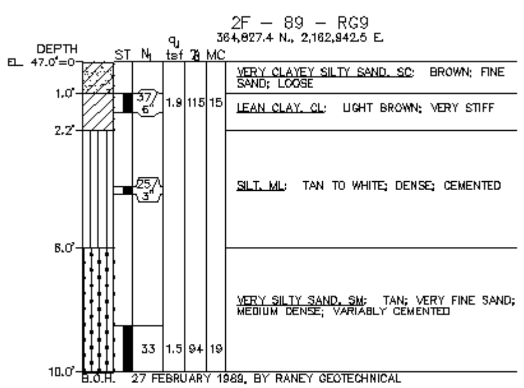
LOCATION AND VICINITY MAPS, AND LOCATION OF EXPLORATIONS
APRIL 2003

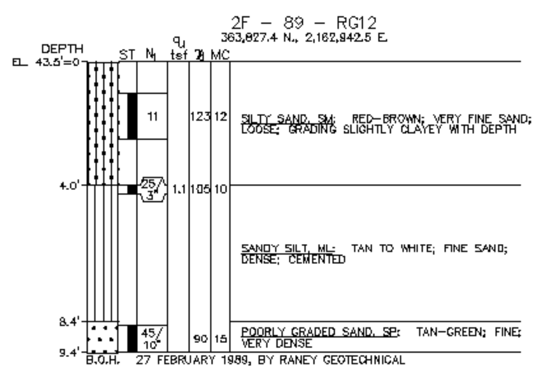
FIGURE
1











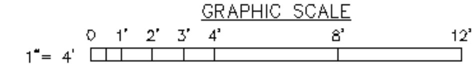
LEGEND: (RANEY GEOTECHNICAL)

ST	SAMPLE TYPE.
N_1	NUMBER OF BLOWS WITH THE MODIFIED CALIFORNIA SAMPLER (2" I.D.)
q_u	UNCONFINED COMPRESSIVE STRENGTH, TSF.
γ_d	FIELD DRY DENSITY, PCF.
MC	MOISTURE CONTENT.

NOTES:

1. LOCATION OF EXPLORATIONS IS SHOWN ON FIGURE NO. 1.
2. OTHER LOGS OF EXPLORATIONS ARE SHOWN ON FIGURE NOS. 3 THROUGH 5.

GRAPHIC SCALE



Designed by J. B.
Dwn by R.L.T.
Reviewed by
File name
Plot date
Plot scale

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LOGS OF EXPLORATIONS
2F-89-RG3, -4, -8, -9 AND 12
APRIL 2003

FIGURE
2

2F-03-20

N XXX,XXX; E X,XXX,XXX

EL. ±XXXX' = 0

DEPTH	USCS	N	N_{60}	GR	SA	FI	LL	PI	MC	Description
0–2.0'	CL	7	9	–	–	–	–	–	–	SANDY LEAN CLAY, CL: Stiff; moist; strong brown; 60% medium plasticity fines; 40% fine sand; no reaction to HCl; no odor
2.0'–4.0'	SC-SM	4	5	1	65	34	21	5	–	SILTY, CLAYEY SAND, SC-SM: Loose; moist; dark yellowish-brown; fine to medium (mostly fine, with a trace of coarse) sand; low plasticity fines; gravel to 3/8 inch; no reaction to HCl; no odor
				–	–	–	–	–	–	
4.0'–10.0'	CL	48	64							LEAN CLAY WITH SAND, CL: Hard; moist; strong brown; 80% medium plasticity fines; 20% fine sand; no reaction to HCl; no odor
		34	45	–	–	–	–	–	–	
		49	65							
10.0'–12.0'	SM	31	41	0	84	16	–	NP	–	SILTY SAND, SM: Dense; moist; light olive-brown; fine to medium (mostly fine, with a trace of coarse) sand; nonplastic fines; no reaction to HCl; no odor
				–	–	–	–	–	–	
12.0'–14.0'	CL	R	R	–	–	–	–	–	–	SANDY LEAN CLAY, CL: Hard; moist; strong brown; 70% medium plasticity fines; 30% fine to medium sand; no reaction to HCL; no odor; moderate iron oxide staining
14.0'–18.0'	SM	69	92	3	55	42	36	5	–	SILTY SAND, SM: Very dense; moist; brownish-yellow; fine to medium (mostly fine, with scattered coarse) sand; low to medium plasticity fines; gravel to 1/2 inch; no reaction to HCl; no odor; moderate iron oxide staining
		R	R	–	–	–	–	–	–	
18.0'–20.0'	SP-SM	50	67	0	91	9	–	–	–	POORLY GRADED SAND WITH SILT, SP-SM: Very dense; moist; yellowish-brown; fine to medium (mostly fine, with a trace of coarse) sand; nonplastic fines; no reaction to HCl; no odor
				–	–	–	–	–	–	
20.0'–22.0'	SP	53	71	–	–	–	–	–	–	POORLY GRADED SAND, SP: Very dense; moist; yellowish-brown; 95% fine to medium sand; 5% nonplastic fines; no reaction to HCl; no odor. From 21.2' to 21.5' diatomaceous
22.0'–34.7'	SP	28	37							POORLY GRADED SAND, SP: Dense; moist; yellowish-brown; 95% fine to medium (with a trace of coarse) sand; 5% nonplastic fines; no reaction to HCl; no odor
		30	40							At 26.0' weak iron oxide staining
		29	39							
				–	–	–	–	–	–	
		29	39							
		28	37							From 30.7' to 30.9' band of iron oxide staining
		29	39							At 32.0' weak iron oxide staining
34.7'–35.5'	CL	64	85	–	–	–	–	–	–	LEAN CLAY, CL: Hard; moist; light brownish-gray; 90% medium plasticity fines; 10% fine sand; no reaction to HCl; no odor

35.5' B.O.H. (11 Mar 2003)

2F-03-21

N XXX,XXX; E X,XXX,XXX

EL. ±XXXX' = 0

DEPTH	USCS	N	N_{60}	GR	SA	FI	LL	PI	MC	Description
0–2.0'	SC	8	11	–	–	–	–	–	–	CLAYEY SAND, SC: Firm; moist; light yellowish-brown; 60% hard, fine to coarse, subangular to subrounded sand; 40% medium plasticity fines; trace of hard, subrounded gravel to 3/4 inch; no reaction to HCl; no odor. From 0.5' to 0.8' fine sand lens
2.0'–6.0'	SC	8	11	6	58	36	26	9	–	CLAYEY SAND, SC: Firm; moist; light yellowish-brown and strong brown; fine to medium (mostly fine, with scattered coarse) sand; low plasticity fines; gravel to 1/2 inch; no reaction to HCl; no odor
		10	13	–	–	–	–	–	–	
6.0'–7.0'	SC			–	–	–	–	–	–	CLAYEY SAND, SC: Firm; moist; strong brown; 60% fine sand; 40% medium plasticity fines; no reaction to HCl; no odor
7.0'–8.0'	SM	8	11	–	–	–	–	–	–	SILTY SAND, SM: Firm; moist; strong brown; 60% fine sand; 40% low plasticity fines; no reaction to HCl; no odor
8.0'–10.0'	SM	8	11	0	68	32	–	NP	–	SILTY SAND, SM: Firm; moist; dark brown; fine to medium (mostly fine) sand; nonplastic fines; no reaction to HCl; no odor
				–	–	–	–	–	–	
10.0'–12.0'	SP-SM	9	12	–	–	–	–	–	–	POORLY GRADED SAND WITH SILT, SP-SM: Firm; moist; dark yellowish-brown; 90% fine sand; 10% low plasticity fines; no reaction to HCl; no odor
12.0'–12.2'	CH			–	–	–	–	–	–	SANDY FAT CLAY, CH: Moist; yellowish-brown; 70% high plasticity fines; 30% fine sand; no reaction to HCl; no odor
12.2'–12.9'	CL	31	41	–	–	–	–	–	–	SANDY LEAN CLAY, CL: Hard; moist; light olive-brown; 60% medium plasticity fines; 40% fine sand; no reaction to HCl; no odor
12.9'–14.0'	SC			–	–	–	–	–	–	CLAYEY SAND, SC: Dense; moist; yellowish-red; 80% fine to medium sand; 20% medium plasticity fines; no reaction to HCl; no odor
14.0'–20.0'	CL	70	93							LEAN CLAY, CL: Hard; moist; yellowish-brown; 90% medium plasticity fines; 10% fine sand; no reaction to HCl; no odor; manganese oxide staining on some of the clay fractures
		R	R	–	–	–	–	–	–	
		71	95							
20.0'–24.0'	SM	61	81							SILTY SAND, SM: Very dense; moist; light yellowish-brown; 75% fine sand; 25% nonplastic fines; no reaction to HCl; no odor
				–	–	–	–	–	–	
		46	61							From 23.0' to 23.5' laminations
24.0'–25.2'	CL	49	65	–	–	–	–	–	–	LEAN CLAY WITH SAND, CL: Hard; moist; grayish-brown; 85% medium plasticity fines; 15% fine sand; no reaction to HCl; no odor; weak iron oxide staining
25.2'–30.2'	ML	37	49							SILT WITH SAND, ML: Very dense; moist; grayish-brown; 85% low plasticity fines; 15% fine sand; no reaction to HCl; no odor. At 26.5' dense
				–	–	–	–	–	–	At 28.0' weak iron oxide staining. At 28.5' very dense
		57	76							
30.2'–34.0'	SM	27	36							SILTY SAND, SM: Dense; moist; light gray; 85% fine sand; 15% nonplastic fines; no reaction to HCl; no odor
				–	–	–	–	–	–	At 32.0' olive-brown; laminations delineated by iron oxide staining
		24	32							At 32.5' grayish-brown
34.0'–35.5'	CL	49	65	–	–	–	–	–	–	LEAN CLAY, CL: Hard; moist; olive-gray; 90% medium plasticity fines; 10% fine sand; no reaction to HCl; no odor

35.5' B.O.H. (11 Mar 2003)

STANDARD PENETROMETER DESCRIPTIVE DATA

COHESIONLESS		COHESIVE	
BLOWS*	RELATIVE DENSITY	BLOWS*	CONSISTENCY
0–4	VERY LOOSE	0–1	VERY SOFT
5–10	LOOSE	2–4	SOFT
11–20	FIRM	5–8	FIRM
21–30	VERY FIRM	9–15	STIFF
31–50	DENSE	16–30	VERY STIFF
51+	VERY DENSE	31+	HARD

* BLOWS PER 1.0 FT. OF PENETRATION OF A 2-INCH O.D. AND 1 3/8-INCH I.D. SAMPLER DRIVEN BY A 140-LB. HAMMER, 30-INCH FREEFALL.

LEGEND:

GR	Gravel, Percent by Weight Passing the 3" Sieve and Retained on the No. 4 Sieve.
SA	Sand, Percent by Weight Passing the No. 4 Sieve and Retained on the No. 200 Sieve.
FI	Fines, Percent by Weight Passing the No. 200 Sieve.
LL	Liquid Limit.
PI	Plasticity Index.
MC	Laboratory Determined Moisture Content In Percent of Dry Weight.
SM	Combined Field Visual Identification and/or Laboratory Classification.
N	Number of Blows with the Standard Penetrometer [Automatic Trip Hammer (80%)].
N_{60}	Corrected Standard Penetrometer Blow Count (See Note 7).
R	Refusal with the Standard Penetrometer (See Note 10).
NP	Nonplastic.
B.O.H.	Bottom of Hole.

NOTES:

1. This drawing is to be used only for approximate location of explorations and description of subsurface conditions.
2. Soil classifications and descriptions are based on field log descriptions in accordance with ASTM D 2488 ("Description and Identifications of Soils, Visual-Manual Procedure") and/or laboratory test results in accordance with ASTM 2487 ("Classification of Soils for Engineering Purposes").
3. All colors shown are in accordance with the Geological Society of America's "Rock Color Chart".
4. All sieve sizes shown are U.S. Standard.
5. Borings were drilled with a CME 55 drill rig using a 3-inch solid stem flight auger on 10, 11 and 29 March 2003.
6. Standard Penetrometer data were obtained in accordance with ASTM D 1586 utilizing an 18" long by 2" O.D. by 1-1/2" I.D. split-barrel sampler.
7. An automatic trip hammer (N) was used for Standard Penetrometer Tests. N_{60} represents the blow counts corrected for energy, where N_{60} = 1.333(N).
8. Groundwater was not encountered at the time of explorations; however, groundwater levels can be expected to fluctuate in response to rainfall variations, particularly in the vicinity of site drainage features.
9. Depending on the soil moisture at the time of construction, the soil encountered may be unstable or potentially unstable. The probability of unstable conditions is highest when the soil moisture is greatest.
10. Refusal with the Standard Penetrometer is defined as one of the following:
    A. 10 blows for no apparent advancement of the sampler; or
    B. 50 blows for less than 6" advancement of the sampler; or
    C. 100 blows for 6" to 18" advancement of the sampler.
11. Location of Explorations is shown on Figure 1.
12. Additional Logs of Explorations are shown on Figures 4 and 5.

GRAPHIC SCALE

1" = 2' 2' 1' 0 2' 4' 6' 8'

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MAGPIE CREEK

LEGEND, NOTES AND LOG OF EXPLORATIONS 2F-03-20 AND -21

DATE:	SCALE:	
22 APR 2003	AS SHOWN	FIGURE 3

MCrB-01.dwg PLOT 1=2 NLB 04-22-2003

2F-03-22

N XXX,XXX; E X,XXX,XXX

EL. ±XXXX' = 0

DEPTH		N	N_{60}	GR	SA	FI	LL	PI	MC	
0 – 4.0'	CL	7 4	9 5	–	–	–	–	–	–	SANDY LEAN CLAY, CL: Stiff; moist; strong brown; 60% medium plasticity fines; 35% fine to medium sand; 5% hard, subrounded gravel to 3/4 inch; no reaction to HCl; no odor At 2.0' yellowish-red At 2.5' firm
4.0' – 5.0'	CL-ML	6	8	0	44	56	19	4	–	SANDY SILTY CLAY, CL-ML: Firm; moist; yellowish-red; low plasticity fines; fine (with scattered medium to coarse) sand; no reaction to HCl; no odor
5.0' – 6.0'	CL			–	–	–	–	–	–	LEAN CLAY, CL: Firm; moist; dark grayish-brown; 90% medium plasticity fines; 10% fine sand; no reaction to HCl
6.0' – 8.0'	SC	49	65	–	–	–	–	–	–	CLAYEY SAND, SC: Very dense; moist; brown; 70% fine to medium sand; 30% medium plasticity fines; no reaction to HCl; no odor
8.0' – 10.0'	SC	30	40	–	–	–	–	–	–	CLAYEY SAND, SC: Dense; moist; strong brown; 85% fine to medium sand; 15% medium plasticity fines
10.0' – 12.4'	SC	20	27	0 –	80 –	20 –	– –	– –	– –	CLAYEY SAND, SC: Very firm; moist; strong brown; fine (with traces of medium to coarse) sand; low plasticity fines; no reaction to HCl; no odor
12.4' – 12.7'	SP			–	–	–	–	–	–	POORLY GRADED SAND, SP: Very dense; moist; brown; 95% fine sand; 5% nonplastic fines; no reaction to HCl; no odor
12.7' – 14.0'	SC	46	61	–	–	–	–	–	–	CLAYEY SAND, SC: Very dense; moist; yellowish-brown; 85% fine to medium sand; 15% medium plasticity fines; no reaction to HCl; no odor
14.0' – 16.0'	SM	68	91	–	–	–	–	–	–	SILTY SAND, SM: Very dense; moist; yellowish-brown; 80% fine sand; 20% nonplastic fines; no reaction to HCl; no odor From 15.2' to 15.3' band of diatomaceous material similar to poorly graded sand
16.0' – 32.0'	SP-SM	48 35 29 23 24 24 26 31	64 47 39 31 32 32 35 41	– 0 –	– 89 –	– 11 –	– – –	– NP –	– – –	POORLY GRADED SAND WITH SILT, SP-SM: Very dense; moist; yellowish-brown; fine to medium (mostly fine, with a trace of coarse) sand; nonplastic fines; no reaction to HCl; no odor At 18.5' dense At 20.0' weak iron oxide staining At 22.0' no iron oxide staining At 26.0' weak iron oxide staining At 28.0' no iron oxide staining From 31.2' to 31.4' bands of iron oxide staining and manganese oxide staining
32.0' – 34.0'	ML	32	43	–	–	–	–	–	–	SILT WITH SAND, ML: Dense; moist; yellowish-brown; 85% low plasticity fines; 15% fine sand; no reaction to HCl; no odor
34.0' – 35.4'	ML	R	R	–	–	–	–	–	–	SILT, ML: Very dense; moist; yellowish-brown; 90% low plasticity fines; 10% fine sand; no reaction to HCl; no odor
35.4' B.O.H.										(10 Mar 2003)

2F-03-23

N XXX,XXX; E X,XXX,XXX

EL. ±XXXX' = 0

DEPTH		N	N_{60}	GR	SA	FI	LL	PI	MC	
0 – 2.0'	SC	9	12	–	–	–	–	–	–	CLAYEY SAND WITH GRAVEL, SC: Firm; dry to moist; light yellowish-brown; 60% fine to coarse, subrounded sand; 25% hard, subrounded gravel to 1 inch; 15% medium plasticity fines; no reaction to HCl; no odor
2.0' – 4.0'	SC	5	7	–	–	–	–	–	–	CLAYEY SAND, SC: Loose; moist; yellowish-brown; 60% fine to medium sand; 40% medium plasticity fines; no reaction to HCl; no odor; iron oxide staining throughout sample; easy drilling
4.0' – 6.0'	SC-SM	15	20	2 –	49 –	49 –	19 –	5 –	– –	SILTY, CLAYEY SAND, SC-SM: Firm; moist; yellowish-red; fine to medium (mostly fine, with a trace of coarse) sand; low plasticity fines; gravel to 1/2 inch; no reaction to HCL; no odor; iron oxide staining which gives a reddish color; easy drilling
6.0' – 6.5'	CL			–	–	–	–	–	–	LEAN CLAY, CL: Moist; grayish-brown; 90% medium plasticity fines; 10% fine sand
6.5' – 8.0'	SC	64	112	–	–	–	–	–	–	CLAYEY SAND, SC: Very dense; dry to moist; brown; 70% fine to medium sand; 30% medium plasticity fines; no reaction to HCl; strong iron oxide staining
8.0' – 13.2'	SM	32 24 39	43 32 52	1 –	81 –	18 –	– –	– –	– –	SILTY SAND, SM: Dense; moist; dark yellowish-brown; fine (with scattered medium to coarse) sand; nonplastic fines; gravel to 3/8 inch; no reaction to HCl; trace of charcoal At 10.0' no charcoal; iron oxide staining At 12.5' very dense At 12.9' olive-brown
13.2' – 14.0'	SP-SC			–	–	–	–	–	–	POORLY GRADED SAND WITH CLAY, SP-SC: Very dense; moist; brown; 90% fine to medium sand; 10% fines; no reaction to HCl; no odor
14.0' – 16.0'	CL	R	R	–	–	–	–	–	–	LEAN CLAY WITH SAND, CL: Hard; moist; light yellowish-brown; 75% medium plasticity fines; 25% fine sand; no reaction to HCl; no odor; weak iron oxide staining From 14.8' to 15.0' diatomaceous material similar to poorly graded sand
16.0' – 16.7'	SM			–	–	–	–	–	–	SILTY SAND, SM: Dense; moist; light olive-brown; 60% fine sand; 40% nonplastic fines; no reaction to HCl; no odor
16.7' – 20.3'	SP	26 23	35 31	–	–	–	–	–	–	POORLY GRADED SAND, SP: Dense; moist; light brownish-gray; 95% fine to medium sand; 5% nonplastic fines; no reaction to HCl; no odor
20.3' – 20.6'	SP			–	–	–	–	–	–	POORLY GRADED SAND, SP: Dense; moist; light brownish-gray; 95% fine to medium (with a trace of coarse) sand; 5% nonplastic fines; no reaction to HCl; no odor
20.6' – 25.2'	SP	23 19 21	31 25 28	–	–	–	–	–	–	POORLY GRADED SAND, SP: Very firm; moist; light brownish-gray; 95% fine to medium sand; 5% nonplastic fines; no reaction to HCl; no odor At 22.5' very firm
25.2' – 25.5'	SP			–	–	–	–	–	–	POORLY GRADED SAND, SP: Very firm; moist; light brownish-gray; 95% fine to coarse, subangular to subrounded sand; 5% nonplastic fines; no reaction to HCl; no odor
25.5' – 30.0'	SP	24 20	32 27	–	–	–	–	–	–	POORLY GRADED SAND, SP: Dense; moist; light brownish-gray; 95% fine to medium sand; 5% nonplastic fines; no reaction to HCl; no odor At 28.0' weak iron oxide staining At 28.5' very firm
30.0' – 32.0'	SP	18	24	–	–	–	–	–	–	POORLY GRADED SAND, SP: Very firm; moist; alternating bands delineated by dark grayish-brown and light olive-brown; 95% fine to medium sand; 5% nonplastic fines; no reaction to HCl; no odor
32.0' – 35.5'	CL	52 55	69 73	–	–	–	–	–	–	LEAN CLAY WITH SAND, CL: Hard; moist; light olive-brown; 85% medium plasticity fines; 15% fine sand; no reaction to HCl; no odor
35.5' B.O.H.										(10 Mar 2003)

NOTES:

1. Location of Explorations is shown on Figure 1.
2. Legend, Notes and additional Logs of Explorations are shown on Figures 3 and 5.

GRAPHIC SCALE

1" = 2' 2' 1' 0 2' 4' 6' 8'

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MAGPIE CREEK

LOG OF EXPLORATIONS 2F-03-22 AND 2F-03-23

DATE:	SCALE:	
22 APR 2003	AS SHOWN	FIGURE 4

MCrB-02.dwg PLOT 1=2 NLB 04-22-2003

2F-03-24

N XXX,XXX; E X,XXX,XXX

Drilled at levee crown; gravel

EL. ±XXXX' = 0

DEPTH		N	N_{60}	GR	SA	FI	LL	PI	MC	
0 – 2.0'	SC	6	8	–	–	–	–	–	–	CLAYEY SAND, SC: Loose; moist; brown; 60% fine sand; 40% low plasticity fines; trace of gravel to 5/8 inch; no reaction to HCl; no odor
2.0' – 4.0'	SM	11	15	–	–	–	–	–	–	SILTY SAND, SM: Firm; moist; brown; 70% fine sand; 30% low plasticity fines; no reaction to HCl; no odor
4.0' – 6.0'	SC	4	5	–	–	–	–	–	–	CLAYEY SAND, SC: Loose; moist; brown; 85% fine sand; 15% medium plasticity fines; no reaction to HCl; no odor
6.0' – 10.0'	SM	2	3	–	–	–	–	–	–	SILTY SAND, SM: Very loose; moist; brown; fine to medium (mostly fine) sand; low plasticity fines; no reaction to HCl; no odor
		20	27	0	60	40	–	–	–	At 8.5' very firm At 9.3' wet
10.0' – 12.0'	CL-ML	46	61	0	45	55	28	7	–	SANDY SILTY CLAY, CL-ML: Hard; moist; tan; low plasticity fines; fine to medium (mostly fine, with a trace of coarse) sand; no reaction to HCl; no odor; weak iron oxide staining; trace of charcoal
12.0' – 14.0'	SC-SM	28	37	0	60	40	22	5	–	SILTY, CLAYEY SAND, SC-SM: Dense; moist; brown; fine to medium (mostly fine) sand; low plasticity fines; no reaction to HCl; no odor; weak iron oxide staining; trace of charcoal
14.0' – 14.8'	SM	42	56	–	–	–	–	–	–	SILTY SAND, SM: Very dense; moist; reddish-brown; 85% fine to medium sand; 15% nonplastic fines; no reaction to HCl; no odor; orangish color may be iron oxide staining
14.8' – 16.0'	SC			–	–	–	–	–	–	CLAYEY SAND, SC: Very dense; moist; brown; 65% fine sand; 35% medium plasticity fines; no reaction to HCl; no odor; weak iron oxide staining; trace of charcoal
16.0' – 18.0'	SM	59	79	–	–	–	–	–	–	SILTY SAND, SM: Very dense; moist; brown; 65% fine sand; 35% low plasticity fines; no reaction to HCl; no odor
18.0' – 26.0'	ML	45	60	–	–	–	–	–	–	SANDY SILT, ML: Very dense; moist; brown; 65% low plasticity fines; 35% fine sand; no reaction to HCl; no odor; shoe came off and was at the bottom of the hole
		42	56							
		56	75	–	–	–	–	–	–	SILT, ML: Very dense; moist; brown; 90% nonplastic fines; 10% fine sand; no reaction to HCl; no odor
		79	105							
26.0' – 28.0'	SM	26	35	–	–	–	–	–	–	SILTY SAND, SM: Dense; moist; gray; 65% fine sand; 35% nonplastic fines; no reaction to HCl; no odor From 26.3' to 26.5', 26.6' to 26.7' and 26.75' to 26.8' fine sand lenses
28.0' – 30.0'	ML	41	55	–	–	–	–	–	–	SANDY SILT, ML: Very dense; moist; gray; 60% nonplastic fines; 40% fine sand; no reaction to HCl; no odor
30.0' – 34.4'	SM	42	56	–	–	–	–	–	–	SILTY SAND, SM: Very dense; moist; dark gray; 85% fine sand; 15% nonplastic fines; no reaction to HCl; no odor
32.0'										SILTY SAND, SM: Very dense; moist; dark gray; 70% fine sand; 30% nonplastic fines; no reaction to HCl; no odor
		40	53	–	–	–	–	–	–	SANDY SILT, ML: Very dense; moist; gray; 75% nonplastic fines; 25% fine sand; no reaction to HCl; no odor
34.4' – 34.8'	ML	R	R	–	–	–	–	–	–	
34.8' – 35.5'	CL			–	–	–	–	–	–	SANDY LEAN CLAY, CL: Hard; moist; tan; 85% medium plasticity fines; 15% fine sand; no reaction to HCl; no odor
35.5'	B.O.H.									(28 Mar 2003)

NOTES:

1. Location of Explorations is shown on Figure 1.
2. Legend, Notes and additional Logs of Explorations are shown on Figures 3 and 4.

GRAPHIC SCALE

1" = 2'   2' 1' 0 2' 4' 6' 8'

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MAGPIE CREEK

LOG OF EXPLORATION
2F-03-24

DATE:	SCALE:	
22 APR 2003	AS SHOWN	FIGURE 5

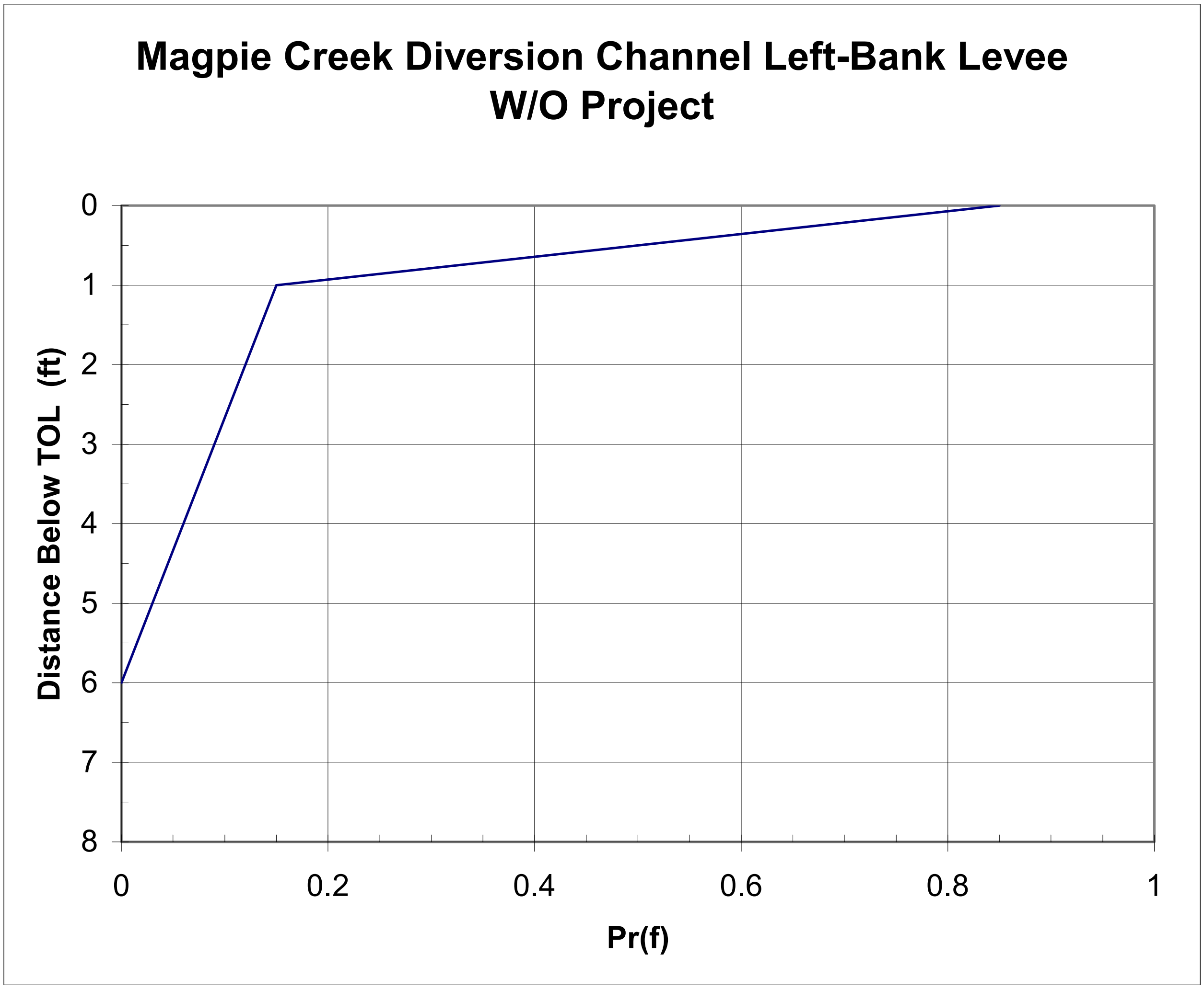
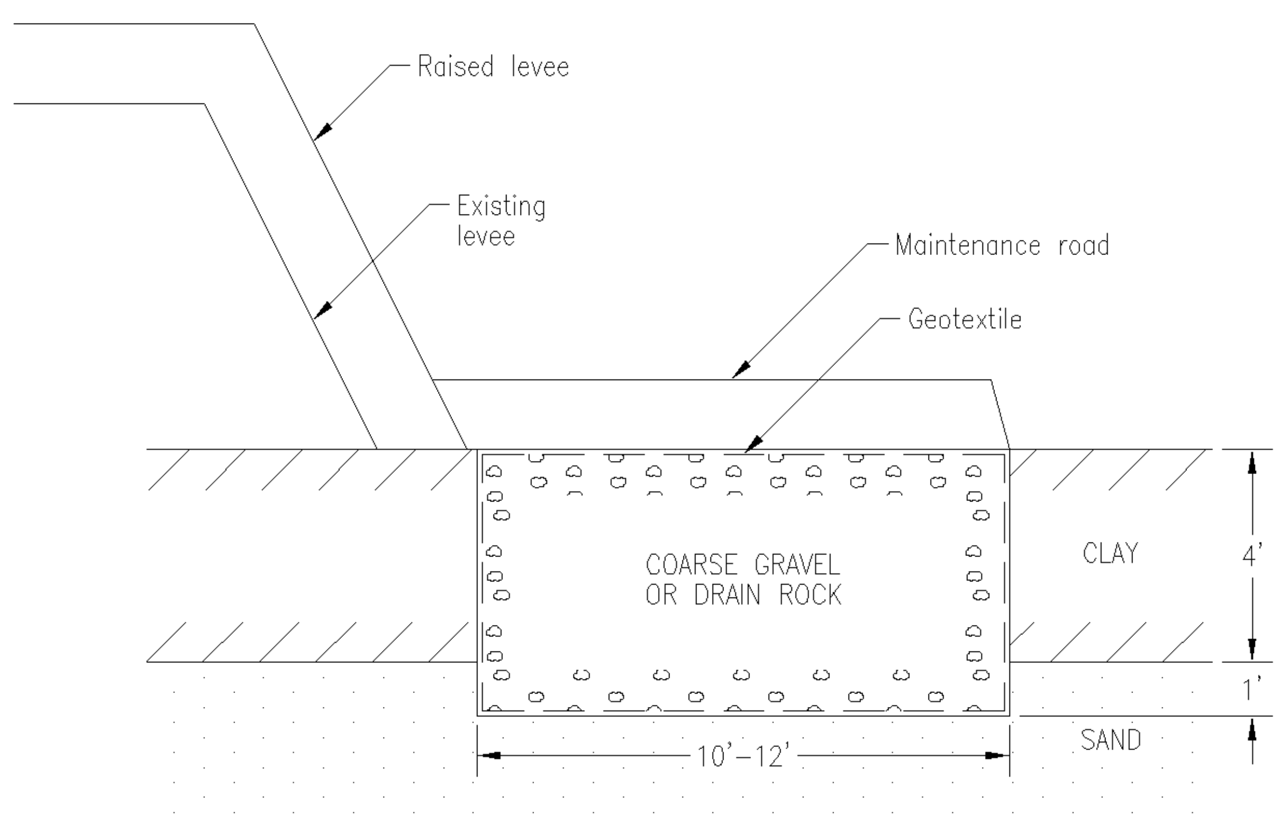

Magpie Creek Diversion Channel Left-Bank Levee
W/O Project
Distance Below TOL (ft)
0
1
2
3
4
5
6
7
8
0
0.2
0.4
0.6
0.8
1
Pr(f)

FIGURE 6

MCrFig07.dwg PLOT 1=1 NLB 05-08-2003



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MAGPIE CREEK

PERVIOUS TOE DRAIN DETAIL

DATE:	SCALE:	
8 MAY 2003	NONE	FIGURE 7

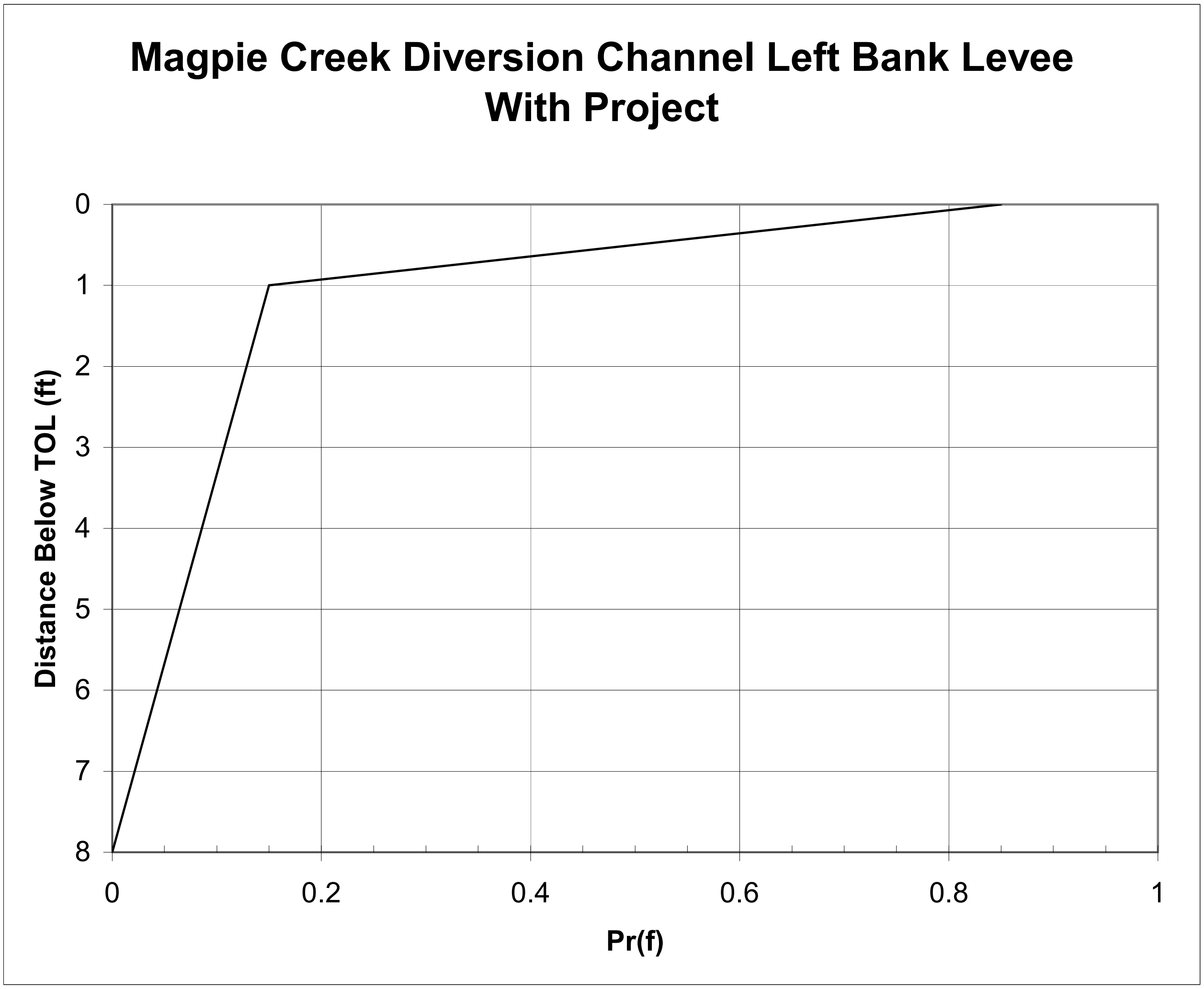
Magpie Creek Diversion Channel Left Bank Levee
With Project
Distance Below TOL (ft)
0
1
2
3
4
5
6
7
8
0
0.2
0.4
0.6
0.8
1
Pr(f)

FIGURE 8